THURSDAY, JANUARY 11, 1877

FERMENTATION

Études sur la Bière. Par M. L. Pasteur. (Paris: Gauthier-Villars).

I.

IN a recent notice of an article on Brewing contributed by Mr. Pooley to Stanford's "British Manufacturing Industries," some statistics were quoted showing the gigantic development which the production of beer has acquired in the United Kingdom. The amount of beer manufactured in the British Islands, vast though it be, forms yet but a small portion of that made throughout the world. Probably no industry—saving agriculture—employs so large an amount of capital as that of brewing and the various industries supported by it. Important though this old and at present vastly extended industry be, it is yet one which, until ve recently, scientific methods of investigation had done but little to add to our knowledge of the complex phenomena underlying the apparently simple art, and therefore even less in preventing the serious losses constantly occurring even with the most careful manufacturer.

The valuable contribution to our knowledge of the biological aspect of fermentation, which M. Pasteur has just given to the world, is a worthy sequel to the classical researches described by the illustrious chemist in the papers read before the French Academy during the last fifteen years, and summarised by him in a popular form in his "Études sur le Vin," and "Études sur le Vinaigre." These important works, containing the results of long years of laborious and brilliant research, have done much to remove the charge brought against science, and have indeed become to the brewer and wine-grower as the brightening sky to the mariner groping his way in fog and uncertainty to his haven. The grateful recognition of twenty years fruitful labour is due alike from practical and scientific men to the illustrious investigator of the Biology of Fermentation, and he certainly will not deem it the less hearty and sincere if occasional exception here or elsewhere be taken to some of his propositions.

Before considering Fermentation and the recent views promulgated by Pasteur and others regarding the interesting and complex phenomena grouped under this term, it will be useful to discuss the changes produced in the malting and mashing processes of the brewer as necessary precursors to the greater change produced in Fermentation properly so-called. Let us, then, examine the change brought about by the action of water and heat on the grain of any of our common cereals—barley, for example; if this be ground and digested for a few hours at a temperature of 60° C. with five or six times its weight of water, it will be found that the whole, or nearly the whole—this depending upon the comparative activity of the albuminous matters present—of the insoluble starch will be changed into products soluble in water. By the agency of the albuminous ferments or alterative agents water will be assimilated and dextrine and Glucose and products of transformation intermediate between these will be obtained.

This reaction is general, and applies not only to the grain of our common cereals, but also to other stored-up amylaceous vegetable products. While, however, the agency of heat and moisture suffice to bring about this remarkable change, it yet requires too much time, and the products formed are not well adapted to the brewer's wants. Various albumenoid bodies, such as the ptyalin in the saliva, and those in the secretions from the pancreas and intestinal canal in the animal economy intensify the action of the soluble albumenoids in ordinary bread-stuffs, and hence produce a greater hydration, and therefore solution, in a given time. Now the object of malting is to convert some of the inert albumenoids into these more active agents of change, and thus the maltster avails himself of a property existing throughout all vegetable tissues, whereby previously stored-up insoluble amylaceous matter is converted, through the joint agency of moisture, heat, and albumenoid ferments, into soluble sugars, and used along with soluble albumenoid matters for the production of new tissues.

To produce an increase in the albumenoid ferments in barley—the grain chiefly employed in England—the maltster first steeps the grain in water for a period varying from fifty to seventy hours according as the skin is thin or thick, that is, more or less pervious to water. So soon as the desired amount of water has been absorbed, it is removed from the cistern and spread out on the floor of the malt-house, the temperature best suited for the production of sound malt being about 15° C. The germination of the grain commences and is allowed to proceed, with occasional turnings, until the plumule of the young growing plant has advanced far enough up the back of the grain to satisfy the objects which the brewer may have in view. Thus, if a full and somewhat dextrinous ale be required, the plumule is barely allowed to grow to the bend, or *bridge*, of the grain, whereas, if a dry alcoholic ale be required, the growth is allowed to proceed further. According to the growth of the plumule, so does the production of active ferment vary. This point being obtained, the malt is placed on the floor of a kiln, whereby further growth is stopped. Without dwelling with too much detail on this malting, or germinating, process, it will be useful to consider here some of the changes produced. In the first place, by the absorption of water the grain swells and the albumenoid ferments previously existing in the grain are made soluble, and these, by the aid of moisture and heat, begin to act on the starch. Meanwhile, a portion of the insoluble albuminous bodies are rendered soluble, and aid in this conversion of starch, and at the same time, in conjunction with the transformation products of starch, serve to build up the cell structures of the growing plumule and rootlets. Throughout the germinating process carbonic acid and heat are evolved precisely as in the subsequent process of the conversion of sugar into alcohol. The analogy does not, however, rest here, because alcohol is also produced in small quantities. If the growing grain be shut in an air-tight vessel, it will be found that as the growth of the young plant is stopped, the amount of alcohol becomes largely increased, attended at the same time by the production of a large quantity of gas, the chief constituent being carbonic acid. This production of alcohol by vegetable cells has already been noticed in the case of fruits by Lechartier and also by Pasteur. The enormous volume of carbonic acid gas produced without the intervention of *free* oxygen is a fact

of great interest to which we must again refer when considering the action of yeast upon sugar.

In this germinating process we have an example of the way in which insoluble matter stored up, whether in the seed or in the tissues of a plant, becomes digested and used for the production of fresh tissues. This property is not limited to vegetable organisms; in animals, also, we find stored-up matter, fatty or amylaceous, acted upon by albumenoid ferments, and being thus rendered soluble, become available for the building up of fresh structures, or for the production of heat by their oxidation in the system. It would lead us too far to discuss here the manner and the agents by which albuminous food, such as flesh meat, cheese, &c., are made soluble in the human economy. Suffice it here to state that the means by which nature produces the desired end of solution in animal and vegetable alike, are moisture, heat, and albumenoid ferments.

The following analyses by Oudemans show the changes produced in the malting process and in the subsequent drying on the kiln:—

	Barley.	Malt.		
	Air dried.	Air dried.	Kiln dried (pale).	Kiln dried (amber).
Torrefaction products	0·0	0·0	7·8	14·0
Dextrine	5·6	8·0	6·6	10·2
Starch...	67·0	58·1	58·6	47·6
Sugar	0·0	0·5	0·7	0·9
Cellulose	9·6	14·4	10·8	11·5
Albuminous Substances	12·1	13·6	10·4	10·5
Fatty ,, ...	2·6	2·2	2·4	2·6
Ash, &c.	3·1	3·2	2·7	2·7
Total	100·0	100·0	100·0	100·0

These analyses, though made some years since, and differing in some points from our existing knowledge, are yet sufficient for our present purpose. We see that the air-dried malt, when compared with the barley from which it was made, is poorer in starch, and richer in woody fibre.

Again, as regards the changes in the albuminous bodies, still quoting Oudemans, we find—

	Barley.	Malt.
Gluten, soluble in alcohol	0·28	0·34
Albuminous substances coagulable by heat	0·28	0·45
,, ,, not coagulable ...	1·55	2·08
Insoluble albumen	7·59	6·23
Total	9·70	9·10

We notice that there has been a loss of some of the albuminous matters in the germinating process, but at the same time an increase in the soluble or active agents of change, to obtain which the malting process is followed. Let us now examine the changes which the malt undergoes when placed in the brewer's mash tun and submitted to the action of heat and water. In England the amount of water employed varies with the nature of the beer to be made, it may be taken, however, as being about twice the weight of the malt, and the temperature of the mixture of malt and water varies from 63° C. to 67° C. In the course of half-an-hour the insoluble starch is converted into soluble sugars and dextrine. The infusion thus obtained is, however, too dextrinous in character for the production of dry alcoholic ales, but as the process continues, more and more water is assimilated, and finally an infusion is obtained rich in alcohol-yielding sugars.

Many theoretical explanations have been given, and will doubtless yet be given, as to the action and the products formed. We are indebted to the admirable and suggestive researches of O'Sullivan for the first clear exposition of what takes place, or rather of one of the changes which occur. He formulates the reaction thus:—

$$\underset{\text{Starch}}{C_{18}H_{30}O_{15}} + H_2O = \underset{\text{Dextrine}}{C_6H_{10}O_5} + \underset{\text{Maltose}}{C_{12}H_{22}O_{11}},$$

and he states that this is the final action of soluble ferments on starch. This equation, however, expresses only what takes place when a small quantity of malt acts on starch paste at a temperature of only 40° C. to 45° C. We must rather assume the probability of several changes, of which that formulated by O'Sullivan is one. Thus if the amount of starch be large in comparison to the active albumenoid ferments, and if the water and time of infusion be lessened, we obtain a solution having a reducing power on Fehling's liquid equal to 33 per cent. of glucose. On the other hand, if the conditions be reversed, that is, if we increase the time, the amount of ferment, and the water, we obtain an infusion having a reducing power equal to 66 per cent. of glucose.

Here, however, the action ceases, and the so-called diastase of malt is unable to carry on the hydration beyond the point last-mentioned, where we obtain a solution which reduces Fehling's liquid to the extent of two-thirds of the reduction obtained when the starch is fully hydrated by weak mineral acids.

Formulating the reactions according to the Fehling reducing products obtained we should have—

$$\left\{\begin{array}{l} \underline{C_{12}H_{20}O_{10} + 2H_2O} \\ \underline{C_{12}H_{20}O_{10}} \\ C_{12}H_{20}O_{10}\,; \end{array}\right.$$

this product having a 33·33 per cent. reducing action. On the other hand, where we continue the action of diastase for a longer period and with more water, we have—

$$\left\{\begin{array}{l} \underline{C_{12}H_{20}O_{10} + 2H_2O} \\ \underline{C_{12}H_{20}O_{10} + 2H_2O} \\ C_{12}H_{20}O_{10}\,; \end{array}\right.$$

this product having a 66·66 per cent. reducing power, and being apparently the final action of diastase on starch. When the hydration of the starch is effected by dilute acid we obtain—

$$\left\{\begin{array}{l} \underline{C_{12}H_{20}O_{10} + 2H_2O} \\ \underline{C_{12}H_{20}O_{10} + 2H_2O} \\ C_{12}H_{20}O_{10} + 2H_2O\,; \end{array}\right.$$

that is, dextrose having the full reducing action.

O'Sullivan's dextrine-maltose reaction might similarly be thus expressed—

$$\left\{\begin{array}{l} \underline{C_{12}H_{20}O_{10} + H_2O} \\ \underline{C_{12}H_{20}O_{10} + H_2O} \\ C_{12}H_{20}O_{10} \end{array}\right.$$

and giving a product having a 44·44 per cent. reducing

action. If this be a correct expression it follows that there are two other possible cases where one and three molecules of water are assimilated. Cane-sugar and lactose are isomeric with O'Sullivan's maltose, and are all dextro-rotatory. These three sugars of the formula $C_{12}H_{22}O_{11}$ are all further hydrated by the action of diastase, yeast water, and dilute acids.

Though ignorant of the molecular weights of starch we may yet safely assume in the expression $(C_6H_{10}O_5)_n$ that the value of *n* must be large, and that a molecule of such complexity will yield in addition to dextrine several sugars isomeric with sucrose and with dextrose, and it may be others of greater hydration. In the brewer's mash tun the hydration products vary according to the malt employed and the extent to which the malting process is pushed before the kiln drying action, the more of the active ferment formed the greater the hydration in a given time. The amount of water is an important factor in the hydration process; the greater this is within certain limits the greater the hydration; and lastly, the products vary with the amount of time given to the mashing or hydration fermentation.

Thus we may briefly sum up the changes produced by the statement that the infusion products of starch will be more dextrinous, *i.e.*, least altered according as we lessen the time, the amount of water, and the growth of the plumules in the malting process; and on the other hand the infusion products will be richer in Glucose (dextrose), and therefore attenuate lower in the subsequent fermentation process, according as we increase the amount of water, the time of infusion, and the growth of the plumule. The variations in these directions introduced in the mashing process in English breweries are within a narrow range, and the products formed have a reducing action on Fehling's liquid, varying from 50 per cent. to 55 per cent. of the total hydration possible by the aid of mineral acids.

The use of unmalted grain is prohibited in England, whereas cane-sugar and Glucose (made by the action of dilute acid on grain) are allowed. The variations in the direction of dextrine-increase were until recently very limited, but on the other hand those in the direction of alcohol-yielding sugars are without limit.

Messrs. O'Sullivan and Valentin, in a communication to the Society of Arts (March 17, 1876), have recently shown how the action of dilute sulphuric acid may be so regulated as to obtain O'Sullivan's dextrine-maltose reaction already described.

The hydration by the agency of very dilute sulphuric acid is carried on until the liquid has a rotatory power of $+ 171°$, indicating two parts of maltose (rotatory power $+ 150°$) and one part of dextrine (rotatory power according to O'Sullivan $+ 213°$), *i.e.*,

$$\frac{2 \times 150 + 213}{3} = + 171°.$$

So soon as the polariscope indicates O'Sullivan's reaction to be complete, the further hydration is stopped by the addition of chalk. Should the mixture of dextrine and maltose thus made prove to yield a stable and good-keeping beer, they will have contributed greatly to counteract the evil tendency of recent legislation by which beer more and more alcoholic has been manufactured.

Having briefly examined the hydration of starch by albumenoid alterative ferments in the brewer's mash-tun, we have now to consider the breaking up of the still complex saccharine products of the reaction into bodies of simpler structure, such as alcohol and carbonic acid, which result from the fermentation process properly so called. Though it is with alcoholic fermentation, with its characteristic boiling or disengagement of carbonic acid gas, that we have chiefly to do, at the same time other products of the decomposition of saccharine bodies, such as acetic, lactic, and butyric acids, must necessarily be considered before we can obtain a correct insight into the phenomena which present themselves in the manufacture of beer.

Let us then follow the products formed by the hydration of starch already studied.

The *wort*, as the brewer terms the liquid containing the infusion products of the mash tun, is drawn off from the insoluble matters of the malt, and is then boiled in another vessel along with hops; the amount of this valuable agent of preservation employed depending upon the strength of the wort, the nature of the product desired, and the length of time it has to be kept before being consumed.

By mere boiling, some of the albuminous bodies are rendered insoluble, a further portion is precipitated by the tannin of the hops, and the resulting liquid, being thus deprived of some of the albuminous food materials, is found to be less liable to subsequent destructive changes. The hops at the same time yield a pleasant bitter principle, and essential oils which play no slight part in the preservation of the manufactured beer. Now, unlike the juice of the grape, the infusion of malt is so rich in albuminous matters, that every expedient is adopted to diminish these aids to destruction; hence the process of boiling, the use of tannin, and the employment in the infusion process of hard water containing salts of lime. To its water Burton chiefly owes its reputation for good ale. The boiled wort, when cooled, is placed in fermenting vessels, and *yeast* is added. This addition of yeast is almost universal; at the same time it must be noted that in the production of *Faro* and *Lambick* the Belgian brewer adds no ferment; a similar practice was at one time rather common in England, and is even now occasionally to be found in Wiltshire. In thus adding no ferment, the brewer follows the invariable practice of the wine-maker, who leaves the must or pressed juice to spontaneous fermentation; the wine-grower may reasonably reckon upon a definite decomposition of his must, but the brewer who follows this method can foretell but little of the result. We shall presently see why the wine-grower's must and the brewer's wort comport themselves so differently under apparently the same conditions. The spontaneous fermentation of malt wort, even now so little practised, is doomed to be altogether discontinued within but a few years.

The English brewer, having cooled his wort to a temperature varying from 14° C. to 18° C., and having added yeast, the fermentation commences, the heat, unless checked, rapidly rises, and the yeast greatly increases in quantity, the larger portion of which rises to the surface of the liquid. Hence this is termed *top* or surface fermentation, in order to distinguish it from the Bavarian process, in which the yeast sinks to the bottom of the

liquid. The temperature of the German *bottom* fermentation varies from 5°·5 C. to 7° C., a temperature that can only be maintained by the employment of large quantities of ice.

The *bottom* and *top* yeasts are probably distinct species. M. Pasteur, however, seems to be in error in stating (p. 190) that the bottom yeast may be distinguished by being less spherical than top yeast. It is true that in London and Edinburgh yeast the cells will be found usually round; hard water, however, such as that at Burton, or artificially made so, yields yeast in which the cells are distinctly ovoid in appearance, resembling very closely Bavarian bottom yeast. M. Pasteur further states (pp. 188 and 192) that the bottom yeast yields a beer of finer flavour, and hence argues the replacement of ales produced by top fermentation by those made on the Bavarian system. Here surely he must be thinking rather of the inferior products of the surface fermentation in France and Germany than of those of England and Scotland. His assertions (pp. 12–17) that by bottom fermentation store beers can be produced, whereas those produced by top fermentation must be consumed at once and cannot be transported are certainly strange to an Englishman.

So far from these unfavourable comparisons being true in all cases, the exact opposite is generally the case. Bavarian and other bottom fermentation beers are in fact those which can neither be preserved nor transported without the liberal employment of ice; even that sent from Vienna to London must be kept cold artificially in order to avoid rapid destruction. As regards flavour, there are many who think a glass of Burton pale ale or of good old college rent ale to be superior to any Bavarian beer. The chief cause of the decline in the production of top fermentation beers on the Continent has been the want of attention in the fermentation process, whereas the English brewer, especially the brewer of high-class ales, has been unremitting in his attention to the temperature in fermentation and to the perfect cleansing of the ale. Now where such attention is given it is not difficult to obtain ales which will keep a few years. While objecting to our English produce being so hastily depreciated by M. Pasteur, our brewers will be the first to avail themselves of his biological researches in order to render their produce more stable and better flavoured, without having recourse to the general adoption of the vastly more costly system of bottom fermentation.

Let us now leave this question of the respective value and future development of the two systems of fermentation, and assume that by either the one process or the other we have obtained our glass of beer. The question now naturally presents itself to us, as to others before us, to what is fermentation due? Pasteur's answer to this I propose to discuss next week.

CHARLES GRAHAM

OUR BOOK SHELF

Manual of the Vertebrates of the Northern United States. By David S. Jordan, M.D. (Chicago: Jansen, McClurg, and Co., 1876.)

THIS useful work contains a short diagnostic account of the whole of the vertebrated animals of the Northern United States, and has been written, as the author tells us, to give collectors and students who are not specialists a ready means of identifying the families, genera, and species described. The mammals as well as the birds of North America have been so ably and elaborately treated of by Prof. Baird, Dr. Coues, and others, that those who are studying these branches of zoology will not find this smaller volume of special service, nevertheless we are not acquainted with any work having a range of treatment which includes the reptilia, amphibia, and fishes with the two other classes. The sub-kingdom, as well as each class and order, are concisely defined, and the most modern arrangement is adopted, based upon the best authorities, the relative importance of the characterising features being clearly brought forward. The system of employing artificial keys so useful in botanical determinations, and so successfully employed by Dr. Coues in ornithology, is employed throughout the book, and will, no doubt, be found to work well. A glossary of the principal technical terms used in the body of the book is also appended. As an example of the manner in which the different species are described, we will take that of one of the species of Fly-catchers: "*Empidonax acadicus* (Gm.), Baird. SMALL GREEN-CRESTED FLY-CATCHER.—Clear olive-green; wing bands buffy; whitish becoming yellowish below; yellowish ring about eyes; bill pale below; primaries nearly an inch longer than secondaries; second, third, and fourth primaries nearly equal, and much longer than first and fifth; first much longer than sixth; L. 6; W. 3; T. $2\frac{3}{4}$; Ts. $\frac{2}{3}$; Tcl. $\frac{1}{2}$; E.U.S. frequent." To naturalists on this side the Atlantic the work will be found a valuable one of reference on account of its inclusiveness, and a glance through it makes us feel how useful a similar one on the British vertebrate fauna would prove to students and collectors.

The Emigrant and Sportsman in Canada. By John J. Rowan. (London: Stanford, 1876.)

THIS is a capital book in many respects. Mr. Rowan is himself an old Canadian settler and knows the country well in various aspects. He tells the plain truth as to the suitability of Canada as a field for emigration, and the intending emigrant could not get a better guide as to the resources of the country, and the kind of settlers for which it is adapted. Mr. Rowan is a keen sportsman and has a fair knowledge of zoology. His descriptions of hunting life in Canada are thoroughly interesting and abound with fresh information on the many animals which are still to be found there. Mr. Rowan is a good observer, and some of the information which he gives regarding the animals with whose habits he is familiar may be new even to naturalists. He describes, at considerable length, especially, the habits of the beaver as observed by himself, and adduces some facts to show that previous popular statements with regard to this animal must be to some extent modified. The volume will be found of interest not only to the emigrant, the sportsman, and the naturalist, but to all who love good hunting and trapping stories well told. Its principal defect is the want of an index.

LETTERS TO THE EDITOR

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts. No notice is taken of anonymous communications.*]

On a Mode of Investigating Storms and Cyclones

I SCARCELY know anything more interesting in connection with the investigation of cyclones and of our storms than the theoretical investigations of Reye, Mohn and Guldberg, and the practical ones of Mr. Clement Ley. Mr. Ley's papers in the *Journal* of the Scottish Meteorological Society, iv. 66, 149, 330, have especially attracted my attention. We have to study the